Space Weather Technical Forecast

Issued on Sunday, 17 December 2023 at 12:26 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: G1-G2 likely on Day 1 (17 Dec) in a generally disturbed four-day forecast period. Risk of further R2 and S1 now moderating slightly.

Analysis of Space Weather Activity over past 24 hours
Solar Activity: Solar activity was Low, with the peak flare a long-period C8.3 from AR3514 at 16/1434UTC. There are currently eight sunspot regions on the disc, with AR3513 no longer visible on the west limb but a further new region appearing on the east limb. Most regions appear stable and magnetically unipolar. The main exceptions are the large and complex AR3514, which is now only partially visible near the southwestern limb. The two other regions of note are AR3520, which has seen some alterations but is also difficult to view close to the west limb, and AR3519, which is magnetically straightforward.
Whilst several CMEs have been observed in the last 24 hours, none are considered likely to be Earth directed.

Solar Wind / Geomagnetic Activity: Solar winds, as measured by DSCOVR at L1, initially showed waning combined CME and fast wind effects. A CME arrival then occurred in a data gap sometime between 17/0553-0733 UTC, which is thought to be the expected CME associated with the X-flare on the 14 Dec. Wind speeds declined gradually to around 440 km/s, but jumped after the CME arrived to around 540 km/s. The density declined from above average to average levels, then increased to above average again after the CME arrived, peaking at 31ppcc. The IMF was weak to moderate, briefly peaking at strong near 16nT after the CME arrival. The north-south component varied weakly, often southward directed, then moderately between +15/-11 nT after the CME arrival. The phi angle was mainly positive (away from the Sun). Geomagnetic activity was Quiet to Active, with a G1/Minor Storm interval 17/0300-0600 UTC.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux was on a declining trend, having been raised in response to the recent larger flares from AR3514. It was below the S1/Minor Radiation Storm threshold throughout the last 24 hours, however.
GOES16 high energy (greater than 2MeV) electron flux was mostly at background levels. The 24-hour fluence was well below the Active threshold (1e8 integrated pfu). The observation at 17/0001UTC was 2.56e6 integrated pfu.

Four-Day Space Weather Forecast Summary
Solar Activity: There remains a chance of further Moderate activity and a slight chance of Strong, both largely tied to the fortunes of AR3514, which is due to rotate off the disc during Day 1 (17 Dec). While some further active regions are likely over the eastern solar horizon, these are unlikely to fully compensate, and there is a step-wise moderating risk of significant flares as a result.

Solar Wind / Geomagnetic Activity: The CME from the X2.8 flare from AR3514 on 14 December arrived at L1 in a data gap sometime between 17/0553-0733 UTC. The magnetic field has now turned southward directed, and should this continue through the coming hours, some

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minor, perhaps moderate, geomagnetic storming is possible. There is one further weak possible CME in the forecast, which is low confidence, especially in timing, but may arrive either late on Day 3 or early on Day 4 (19-20 December). In addition, the fast wind from CH82/+ is due on day three, 19 December.
Geomagnetic activity is likely to be Active to G2/Moderate Storm at first, with any G3/Strong Storm intervals now considered unlikely. This easing through Day 2, then a mixture of fast wind and CME influences are likely to bring a lower uptick on Day 3 to 4, with conditions most likely Unsettled to Active but with a chance of G1/Minor Storms.

Energetic Particles / Solar Radiation: GOES16 high energy proton flux is now just very slightly above background, with a slight chance of exceeding S1 again AR3514 flare appropriately. This probability then waning as the sunspot group rotates onto the far side.
Regarding high energy electron flux, CME arrivals are likely to keep these in check at GEO initially, with a brief window then arising before further attenuation by CH82/+. The associated 24-hour electron fluence should therefore mostly remain near current levels, with any more appreciable rise probably delayed until after midweek UTC.

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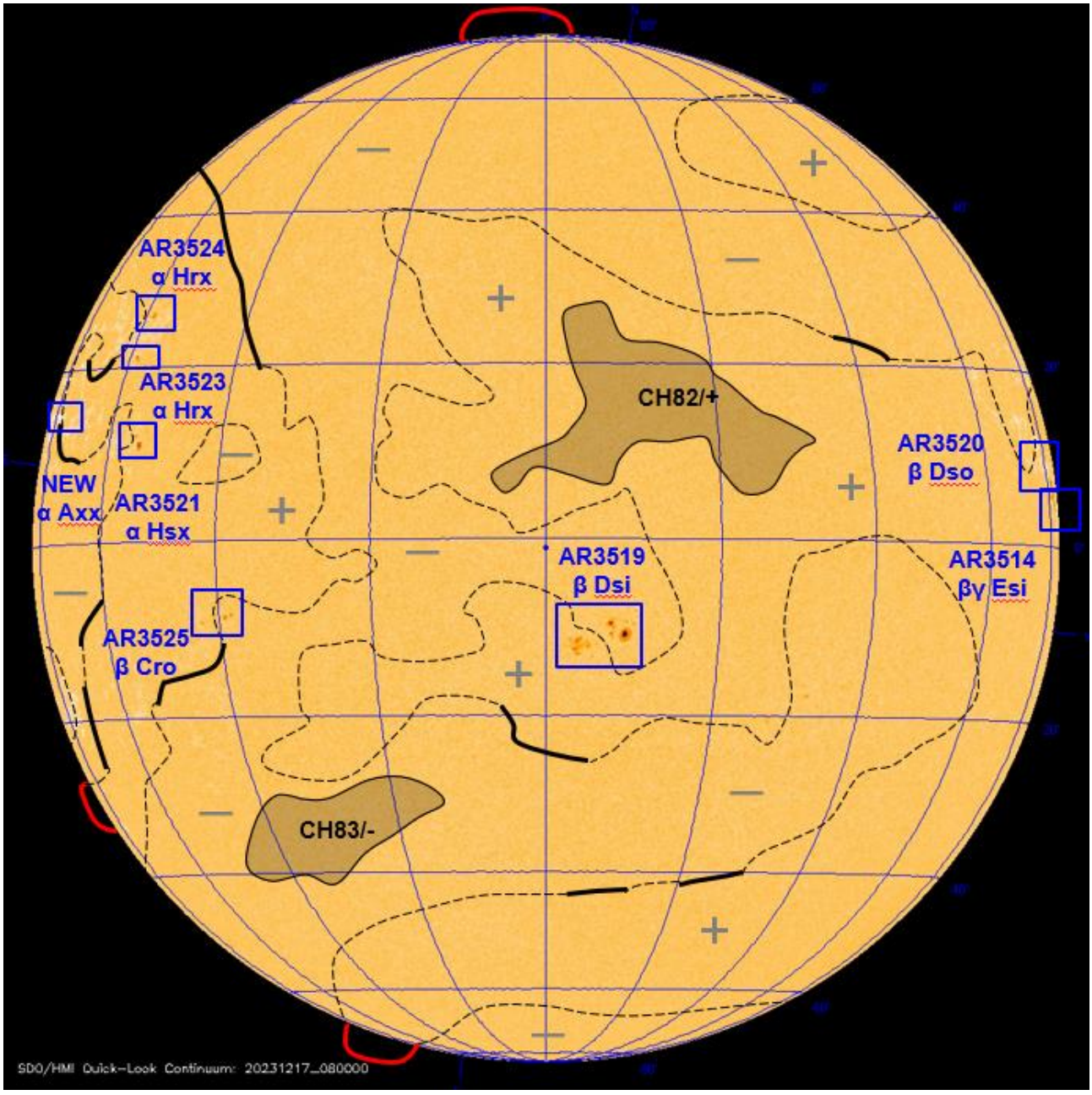
Figure 1. Solar Analysis Valid 17/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Met Office Space Weather Technical Forecast

Geomagnetic Storms:

The CME from the X2.8 flare from AR3514 on 14 December arrived at L1 in a data gap sometime between 17/0553-0733 UTC. The initial arrival appeared to have mostly northward directed Bz, limiting the initial shock. However, the Bz has since turned southward directed. Should this continue through the coming hours, some minor, perhaps moderate, geomagnetic storming is possible.

There is one further weak possible CME in the forecast, from the 15/2100UTC south-centre disc filament eruption. This is low confidence, especially in timing, given the scant, faint coronagraph imagery used for analysis. Given its central position, Earth impacts are considered fairly likely but probably muted for being slow and weak - assuming the correct CME front has been identified and the ejecta were not otherwise reabsorbed. This may arrive either late on Day 3 or early on Day 4 (19-20 December), with uncertainties in the timing also introduced by the current poor coronal hole forecast in Enlil.

The coronal hole-driven forecast is simpler, with CH79 likely having been masked by the previous CME arrival but now easing. This leaves CH82/+ due on day three, 19 December. The onset of CH82 is of moderate confidence, as although a persistent feature, it has had a history of a westward pointing promontory that may produce a slightly earlier onset, although this now appears to have closed. Enlil's treatment of CH82's fast wind is felt to be a little late and large in magnitude, given its behaviour during the previous rotation. Even though we are very near the minimally geoeffective solstice, the intensity of the coronal hole and its history of having produced a G1 on last pass lend themselves to a further chance of similar on 19 December.

All in, the coming four days are likely to be relatively disturbed in terms of geomagnetism, with windows of more favourable conditions generally short-lived and of low confidence - probably most reliably present after the present CME effects have waned and before CH82, i.e. perhaps later Monday 18 and early Tuesday 19 December. Geomagnetic activity is likely to be Active to G2/Moderate Storm at first, with any G3/Strong Storm intervals now considered unlikely. This easing through Day 2, then a mixture of fast wind and CME influences are likely to bring a lower uptick on Day 3 to 4, with conditions most likely Unsettled to Active but with a chance of G1/Minor Storms.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	70	20	30	20
Strong	G3	No	2	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
16/1947	Partial	Filament	S Centre	341 km/s	Late 19 or early 20 Dec	Low confidence

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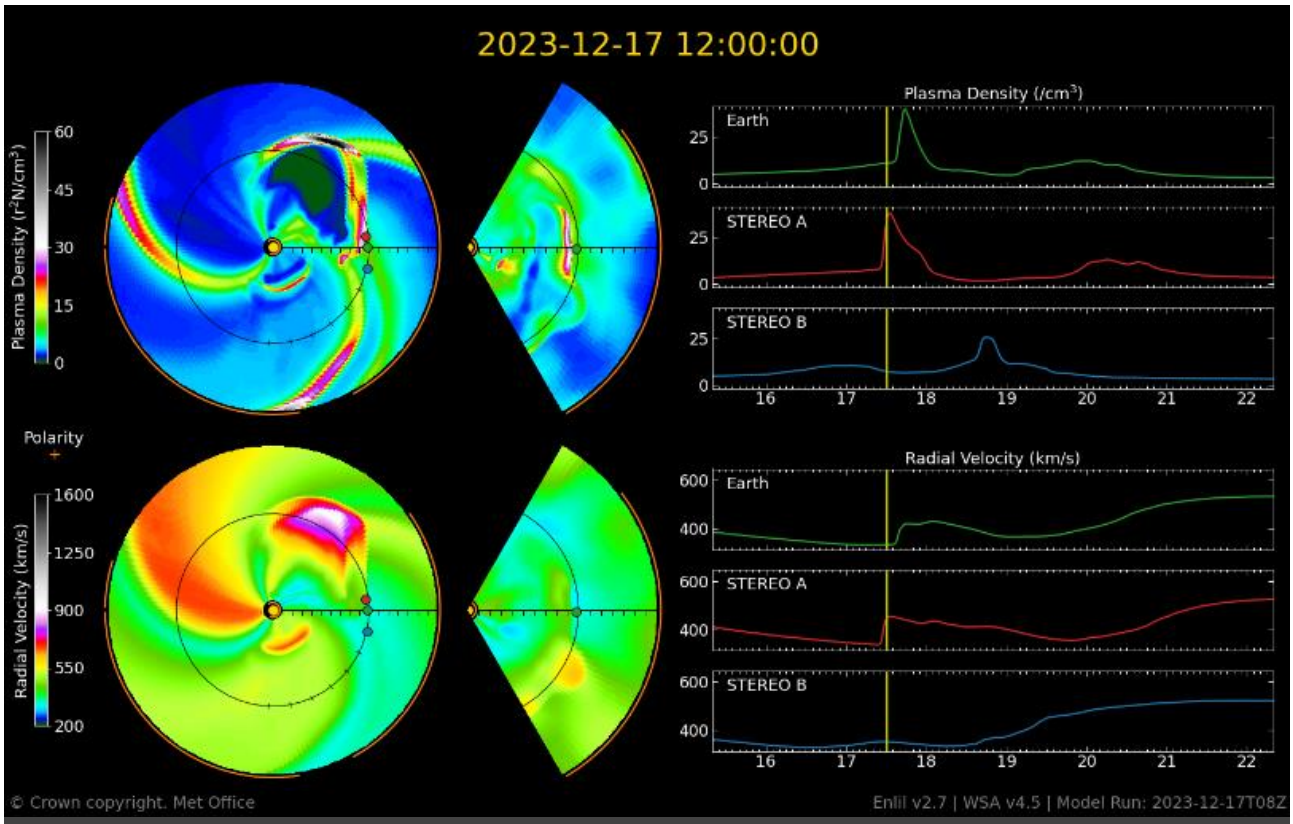
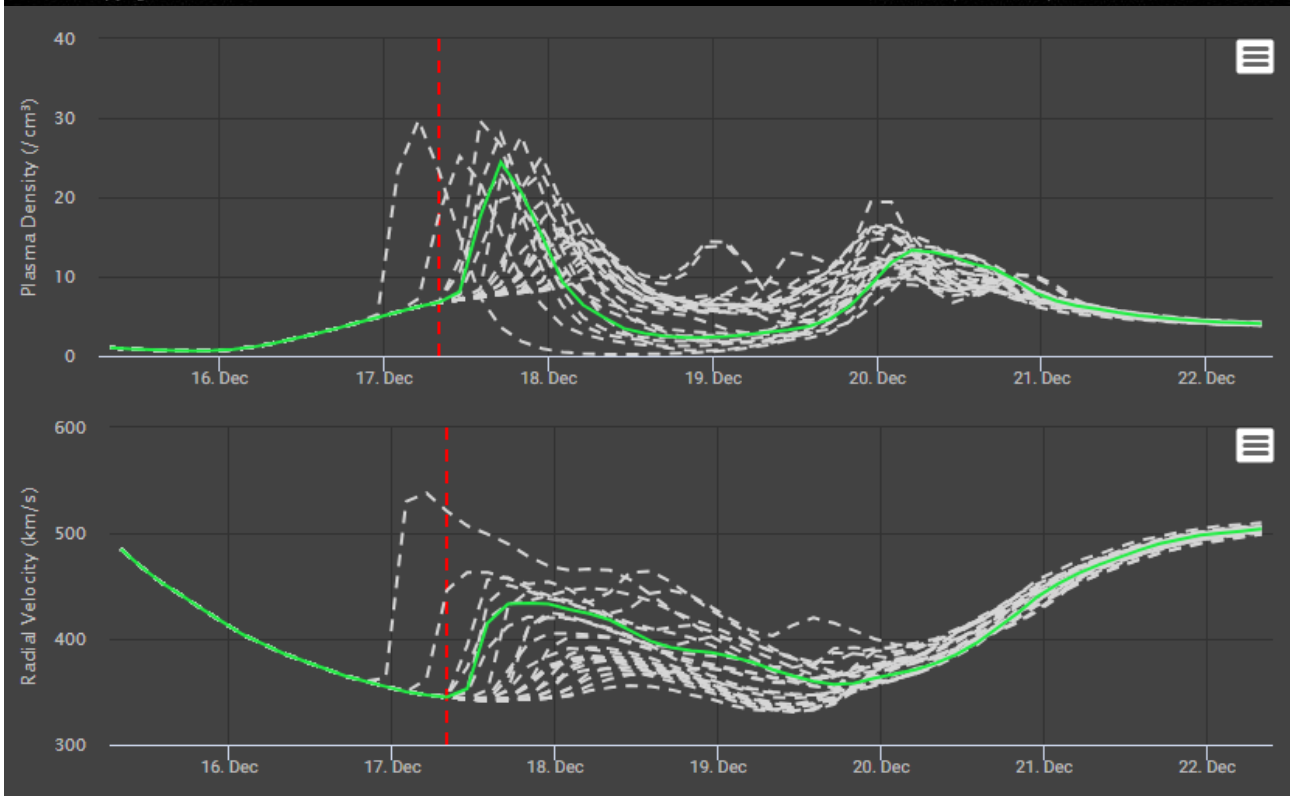
Figure 2: MOSWOC Enlil and ensemble showing CME arrival today (already arrived) and further possible CME arrival late 19 or early 20 Dec. Enlil is also likely to late to bring in the fast wind from CH82, which is preferred on the 19 Dec.





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Radio Blackouts - X-Ray Flares:
The current X-ray forecast is highly dependent on the fortunes of AR3514, with the current daily risk notably higher than the raw disc would otherwise suggest given previous observed activity from this region, although this has been mollified a little as observed activity has fallen. This region is now very close to the limb and as such is no longer fully visible. It is expected to cross onto the far side of the Sun later on Day 1 (17 Dec) and as such there is a step-wise transition downward in the chances of further significant flares. Otherwise, most regions appear stable and magnetically unipolar. The two other regions of note are AR3520, which has seen some alterations but is also difficult to view close to the west limb, and AR3519, which is magnetically straightforward.

There are also the returning Carrington locations of many sunspot regions over the eastern solar horizon, mainly earlier in the period, as far side soundings and limb EUV flux here are not readily backed up by CME and dimming evidence from the oncoming far side to suggest anything comparable making up for the loss of by then Ex-3514.

X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	R1-R2 M Class	No	50	45	40	40
Very Active	R3 to R5 X Class	No	10	5	1	1

Figure 3: X-ray flux at GOES16 and 18, showing only C-class flares in the last 24 hours.

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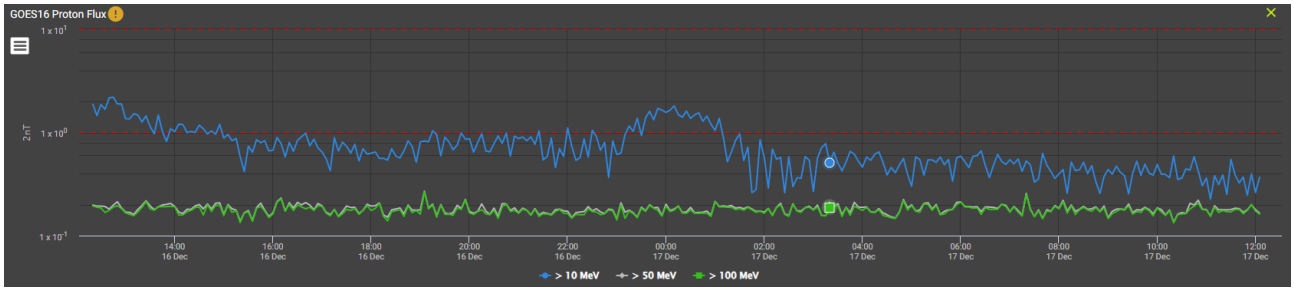
Solar Radiation Storms - (High Energy Protons):
The high energy (greater than 10MeV) proton flux observed by GOES16 has been on a downward trend after peaking at S1 late on 15 Dec in response to activity from AR3514. The observed spectra were relatively soft, with 50 and 100MeV protons unmoved, despite the westward emission location from the X and M-class flares. The breach of S1 was not seen at GOES18 in otherwise very similar spectra, perhaps implying a local effect for GOES16.

Flux levels are now close to background, but there remains a slightly increased risk of further breaches of S1 in the next 24 hours or so. The region responsible for much of the risk departs the Earth-facing side of the Sun during Day 1 (17 Dec), with the risk gradually reducing as it rotates well away from the west limb.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	20	15	10	10
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: Proton flux at GOES16, showing a gradual decline over the last 24 hours.



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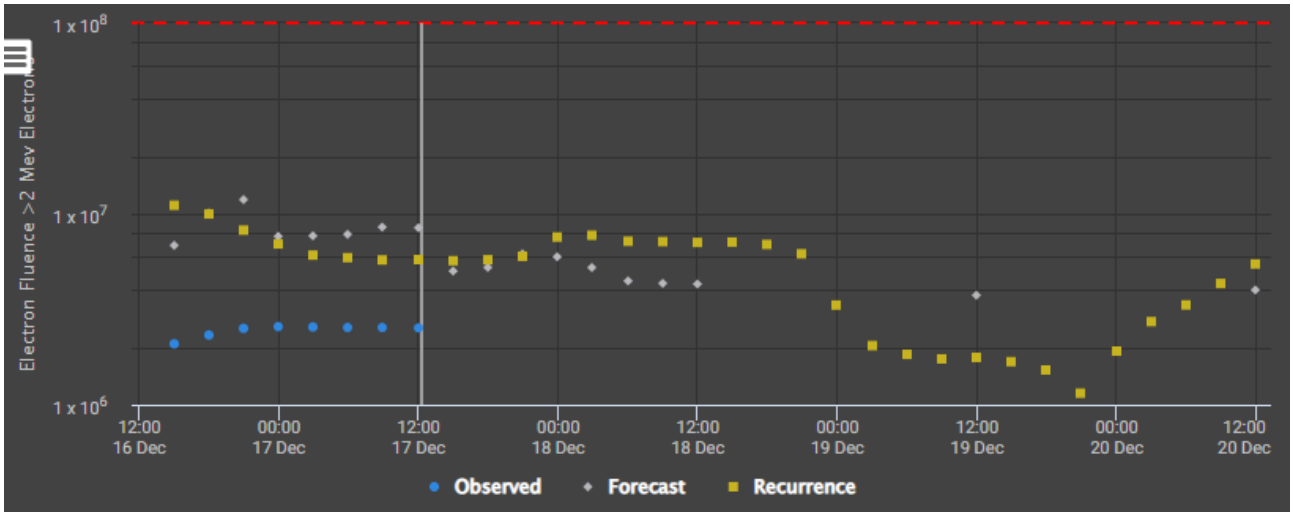
High Energy Electrons Event (≥ 2MeV):

High energy electron flux is currently mostly at background levels, and is expected to remain so in the immediate term. The current CME effects are likely to be compressing the Van Allen belts over the next 24 hours or so, however there is then a window for recovery between the CME effects waning and the fast wind from CH82 arriving on Day 3 (19 Dec). The fast wind and a potential further CME are then likely to suppress levels once again on Days 3 to 4.

This leads to a peak Slight Chance of Active 24-hour integrated fluence on Tuesday 19 December before the coronal hole arrives, with any more assured rise probably then delayed until later in the coming UTC working week as CH82 wanes.

GEO Electron Environment	Level ($cm^{-2}\ sr^{-1}\ day^{-1}$)	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	1	5	20	10
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

Figure 5: MOSWOC REFM, showing fluence well below Active.



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